

Early mortality declines at the dawn of modern growth^{*}

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Abstract

We explore the hypothesis that demographic changes started in the seventeenth and eighteenth centuries are at the root of the acceleration in growth rates at the dawn of the modern age. During this period, life tables for Geneva and Venice show a decline in adult mortality; French marriage registers show an important increase in literacy; historians measure an acceleration of economic growth. We develop an endogenous growth model with a realistic survival law in which rising longevity increases the individual incentive to invest in education and foster growth. We quantitatively estimate that the observed improvements in adult mortality account for 70% of the growth acceleration in the pre-industrial age.

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1 Introduction

Understanding the take-off of traditional societies and their transformation into modern economies is one of the most significant challenges facing economists. Building such a dynamic theory of production and development was already the concern of Rostow (1960). More recently, Galor and Weil (2000) wonder why output started to grow through the Industrial Revolution after thousands of year of “Malthusian” stagnation. They stress the link between population dynamics and the economic take-off. In the same vein, Jones (2001) argues that the density of population is key to understand the industrial revolution: once population had reached a critical mass, growth started to accelerate thanks to more intense exchanges of ideas. In another strand of the literature, authors (see Hansen and Prescott (1998) and Doepke (1999)) have modelled this transition by assuming decreasing returns to scale in the agricultural sector (because of land), constant returns to scale in manufacturing, and an exogenous technological progress. At some point in time, industry becomes profitable and the transition starts.

In this paper, we focus on interesting phenomena that have occurred in Europe before and at the dawn of the Industrial Revolution. First, from the end of the seventeenth century adult mortality started to decline. Second, during the same period significant improvements in literacy were achieved. Finally, growth starts to accelerate during the eighteenth century. In the standard view, the improvements in longevity that Europe has experienced since the eighteenth century are a consequence of better economic conditions. However, many authors argue that the very early decline in mortality should be considered as exogenous to the economic system.¹

In accordance with this argument, we explore the hypothesis that longevity improvements started in the seventeenth and eighteenth centuries caused the acceleration in growth rates at the dawn of the modern age. The story we consider goes as follows: exogenous improvements in adult mortality between 1600 and 1800 increased the individual incentive to build human capital. As a consequence, investment in education rose, which exerted a positive effect on economic growth.

To quantitatively assess the effect of improvements in adult mortality on pre-industrial growth we build a model based on de la Croix and Licandro (1999) and Boucekkine, de la Croix, and Licandro (2002). The attractive feature of this model is to embed a realistic survival law into an endogenous growth model with vintage human capital. It allows to study how shifts in survival probabilities at different ages affect the incentive to invest in human capital and promote growth.

Section 2 presents the relevant facts about mortality, education and growth in the pre-industrial age. After having assessed that adult longevity significantly increased

¹See Perrenoud (1985) and Fridlitzius (1985). Of course, subsequent improvements in longevity (in the nineteenth and twentieth centuries) were largely due to higher living standard.

over the period considered, Section 3 describes the theoretical model linking education and growth to survival probabilities. Section 4 quantitatively estimates the shift in the survival law, calibrates the other parameters of the model and computes the effect of rising longevity on education and growth. Section 5 concludes.

2 Selected Facts

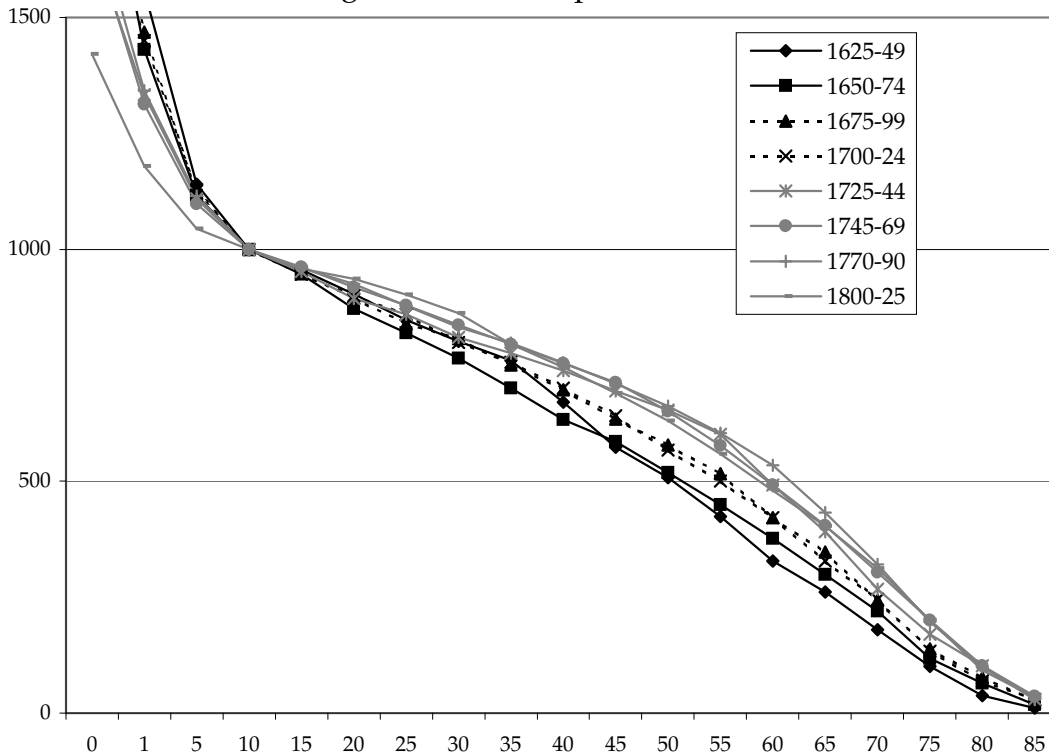
Early Mortality Declines

To assess the role of the decline in mortality in the economic take-off of Western Europe, it is necessary to distinguish the fluctuations of infant mortality from the reduction in the mortality of adults. Infant mortality fluctuates strongly as a function of economic and sanitary conditions, as children will be the first to suffer from bad crops and diseases. Child mortality has a major influence on the estimation of life expectancy at birth. Since improvements in infant mortality have arisen very late in the nineteenth century, it is not surprising that life expectancy at birth shows little trend before that time. Using the data built by Wrigley and Schofield (1981) for England, life expectancy at birth peaks in England at 39.5 years around the year 1575, then drops to 33 years in the period 1670-1750, and rises again and reaches its 1575 level in 1820. Then, it remains steady at 40 years until 1850. However, this absence of large improvement before 1850, due to a high and volatile infant mortality, hides more subtle improvements on the front of adult mortality. We shall eliminate the effects of this volatility on life expectancy estimations to get a much better picture of the evolution of adult mortality.

To study how adult mortality evolved over time, we need cohort life tables at different periods. We have found two data sets adapted to our purposes. The first one is from Perrenoud (1978) who constructed life tables from 1625 to 1825 on the basis of a wide nominative study in Geneva (Switzerland). The second set is built by Beltrami (1951). He uses parish registers to reconstitute age-group dynamics of the Venetian population over the period 1600-1790. Complete life tables are available for the cohorts born between 1600 and 1700; for the cohorts born after 1700 we only have partial tables, since the study ends in 1790. These data sets are presented in Figures 1 and 2, where survival laws are normalized to 1000 at age 10. By doing so, we eliminate the shifts generated by changes in infant mortality and concentrate on the mortality of adults.

The Geneva's picture, Figure 1, displays upward shifts of the curve from one generation to the next. The drop in the death rates essentially concerns the ages 40 to 65. Notice that the end of the curve does not move much, reflecting that the gains in longevity do not translate into a rise in the maximum attainable age. Very few persons live longer than 85.

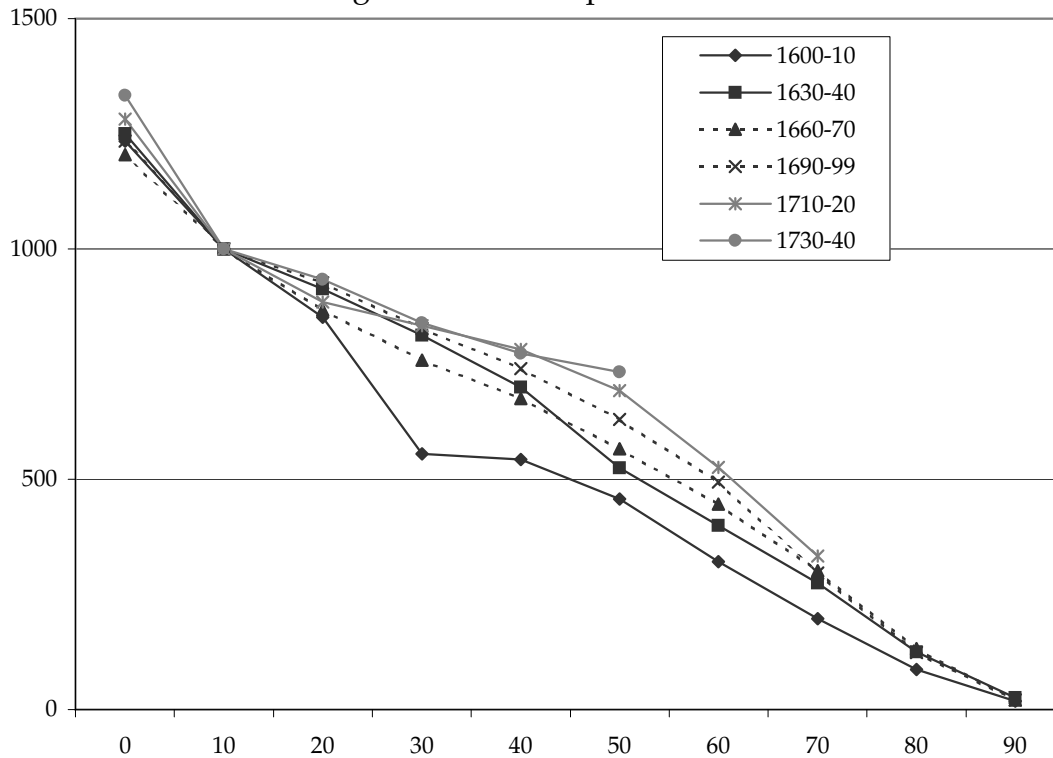
Figure 1: Survival probabilities – Geneva



In Figure 2 we find the same trend in Venice's data, that have been built from different sources. The lower curve represents the survival law for the generation born in 1600-1610. The dip in the curve at the age of 30 reflects the dramatic plague experienced by the city in 1630. The data from this period are thus rather pessimistic about longevity, as they take into account the damage caused by these particularly vigorous epidemics. To have a more prudent view of the improvement in longevity, we can compare the generation born in 1630-1640 to the one born in 1730-1740. There is no plague during this century in Venice (except the one of 1630 that only affects infant mortality of the generation 1630-40). Here again, the gains in longevity are concentrated on the working ages, and life expectancy at 10 increases significantly over the period.

The debate concerning the causes of the initial decline in mortality is not settled yet. It seems that the classical view according to which pre-industrial mortality was reduced when nutritional standards were improved is losing ground. Perrenoud (1985) and Fridlitzius (1985) claim that human factors (nutrition, medicine, sanitary conditions and economy) did not play a prominent role in the first phase of the process. Instead, the decline in mortality should be found elsewhere; it can be connected to changes in immunology and/or improvement in the climate.

Figure 2: Survival probabilities – Venice



Improvements in Education

It is extremely difficult to assess the level of education prevailing before the nineteenth century. Fragmented pieces of evidence suggest that illiteracy was a major problem at the beginning of the seventeenth century. For example, and since we have provided data on Venice, Cipolla (1969) reports that: "In 1607 the Venetian government appointed a commission of four naval officers to decide upon the kind of ships to be used in a war against the pirates. They must have been officers of quality to be chosen for such a purpose; among the four officers, three of them signed their names with a cross."

There were improvements however, as witnessed by the French survey undertaken in 1877 by Maggiolo, who asked 15,928 teachers to count the signatures on marriage registers (see Fleury and Valmary (1957)). They treated 219,047 documents over the period 1686-90 and 344,220 documents over 1786-90. The global results are that 79% of newly married people signed with marks in 1686-90; this percentage drops to 63% in 1786-90. Data are available by departments and Table 1 displays the information for some selected areas. Similar, but less extensive, data are reported for England and Scotland by Stone (1969). Both data sets suggest that the gains in literacy over the eighteenth century were large.

Table 1: Percentage of newly married people who signed with marks

Department	1686-90	1786-90
Bouches du Rhône (Marseilles)	89	80
Gironde (Bordeaux)	86	81
Oise (close to Paris)	62	44
Pas-de-Calais (Flanders)	72	60
Rhône (Lyon, close to Geneva)	88	70
FRANCE	79	63

These gains do not result from the imposition of any compulsory schooling system which were created in Western Europe in the nineteenth century. However, public schools started to develop before. For the Geneva's example, Cipolla (1969) mentions that a Chinese manuscript around 1750 reported that the inhabitants of Switzerland "are strong and broad in stature. They are loyal and honest. In each community public schools have been established." Throughout Europe, cities set up schools run by the municipality (for example, see Schama (1977) on Amsterdam and Rotterdam).

As far as attendance is concerned, some fragmented pieces of evidence are available for some local schools or universities. For example, Chartier, Compère, and Julia (1976) report the number of students in medicine at the Montpellier university over three centuries (1500-1800). The series displays no trend from 1500 to 1730, then rises until the French revolution. The number of students doubled between 1720 and 1780.

Note finally that the increase in the literate population is a prerequisite to develop and diffuse technological innovations. For example, the growth of clock-making and the manufacturing of precision instruments rested on a growing supply of literate craftsman. In Geneva, well-known for the clock-making trade, contracts of apprenticeship generally included the obligation to learn how to read and write during the first year.

The Acceleration of Growth

As reported in Table 2, Maddison (1982) estimates a small acceleration of growth during the eighteenth century at the dawn of the First Industrial Revolution. Indeed, the Industrial Revolution started around 1780 in England (see Stokey (2001) and her quantitative model of the British industrial revolution). However, since the period 1789-1815 is characterized by wars and civil revolutions across Europe, Maddison (2001) retains 1820 as the starting date for the acceleration of growth and technical progress. The same fact is documented by Ladurie (1961) for France: he estimates that the annual growth rate of total GDP (not per capita) increased from 0.33 % over

1700-1750 to 1.32 % between 1750 and the French revolution.

Table 2: Growth in Western Europe

	500-1500	1500-1700	1700-1820	1820-1980
Population	0.0	0.2	0.4	0.9
GDP	0.0	0.3	0.6	2.5
GDP per capita	0.0	0.1	0.2	1.6

3 The Model

To measure the effect of the early gains in life expectancy on education and growth, we use a model adapted from Boucekkine, de la Croix, and Licandro (2002).

Demographic Structure

Time is continuous and at each point in time there is a continuum of generations indexed by the date at which they were born. Each individual has an uncertain lifetime. The unconditional probability for an individual belonging to the cohort t of reaching age $a \in [0, A(t)]$, is given by the survival law

$$m(a, t) = \frac{\alpha(t) - e^{\beta(t)a}}{\alpha(t) - 1}, \quad (1)$$

with both functions $\alpha(t) > 1$ and $\beta(t) > 0$ being continuous.² This two-parameter function is much more realistic than the usual one-parameter function used for example in Kalemli-Ozcan, Ryder, and Weil (2000): like the actual survival laws, it is concave (for $\beta(t) > 0$ and $\alpha(t) > 1$); moreover it allows to model improvements in mortality which do not necessarily affect all ages simultaneously.

The maximum age $A(t)$ that an individual can reach is

$$A(t) = \frac{\log(\alpha(t))}{\beta(t)}. \quad (2)$$

The unconditional life expectancy associated to (1) is

$$\Lambda(t) = \int_t^{t+A(t)} (z-t) \frac{\beta(t)e^{-\beta(t)(z-t)}}{\alpha(t)-1} dz = \frac{\alpha(t) \log(\alpha(t))}{(\alpha(t)-1)\beta(t)} - \frac{1}{\beta(t)}. \quad (3)$$

²Indeed, our model is also consistent with piecewise continuous $\alpha(t)$ and $\beta(t)$ functions, allowing for discontinuities in life expectancy.

An increase in life expectancy can arise either through a decrease in β or an increase in α . These two shifts do not lead to the same changes in the survival probabilities. When α increases, the improvement in life expectancy relies more on reducing death rates for young and middle-age agents. When β decreases, the old agents benefit the most from the drop in death rates, which has an important effect on the maximum age.

Assuming that the size of a newborn cohort is $\zeta e^{n(t)t}$, with $\zeta \in \mathbb{R}_+$ and $n(t) \in \mathbb{R}$, the size of this cohort at time $z > t$ is

$$\zeta e^{n(t)t} m(z - t, t), \text{ for } z \in [t, t + A(t)]. \quad (4)$$

$n(t)$ is the growth rate of population at t , and ζ is a time-independent scale parameter. Although each individual is uncertain concerning the time of his death, the measure of each generation declines deterministically through time.

The size of population at time t is given by

$$P(t) = \int_{t-\bar{A}(t)}^t \zeta e^{n(z)z} m(t - z, z) dz, \quad (5)$$

where $\bar{A}(t)$ is the age of the oldest cohort still alive at time t , i.e., $\bar{A}(t) = A(t - \bar{A}(t))$.

This framework allows us to study situations where the survival law is moving over time, as we observe in the period under consideration.

Production Technology

There is a unique material good, the price of which is normalized to 1, that can be used for consumption. The production function is linear in the stock of human capital:

$$Y(t) = H(t). \quad (6)$$

Hence, firms employ the whole labor force to produce as long as the wage per unit of human capital is lower or equal to one. The equilibrium in the labor market thus implies that the wage per unit of human capital is constant through time and equal to one, i.e., $w(t) = 1$, for all t . The normalization of human capital productivity to unity does not affect the equilibrium.

The Households' Problem

An individual born at time $t, \forall t \geq 0$, has the following expected utility:

$$\int_t^{t+A(t)} c(t, z) m(z - t, t) e^{-\theta(z-t)} dz, \quad (7)$$

where $c(t, z)$ is consumption of generation t member at time z . The pure time preference parameter is θ .

We assume the existence of complete markets. The inter-temporal budget constraint of the agent born at t is:

$$\int_t^{t+A(t)} c(t, z) R(t, z) dz = h(t) \int_{t+T(t)}^{t+A(t)} R(t, z) dz. \quad (8)$$

$R(t, z)$ is the contingent price paid by a member of generation t to receive one unit of the physical good at time z in the case where he is still alive. By definition, $R(t, t) = 1$. The left-hand side is the actual cost of contingent life-cycle consumptions. The right-hand-side is the actual value of contingent earnings. The individual enters the labor market at age $T(t)$ with human capital $h(t)$, and earns a wage $w(z) = 1$ per unit of human capital. Human capital accumulation depends on the time spent on education, $T(t)$, and on the average human capital $\bar{H}(t)$ of the society at birth:

$$h(t) = \frac{\mu}{\eta} \bar{H}(t) T(t)^\eta, \quad (9)$$

where $\eta \in]0, 1[$ and $\mu \in \mathbb{R}_+$ are technological parameters. The presence of $\bar{H}(t)$ introduces the typical externality which positively relates the future quality of the agent to the cultural ambience of the society (through for instance the quality of the school).

The problem of the representative individual of generation t is to select a consumption contingent plan and the duration of his education in order to maximize his expected utility subject to his inter-temporal budget constraint, and given the per capita human capital and the sequence of contingent wages and contingent prices. The corresponding first order necessary conditions for a maximum are

$$m(z - t, t) e^{-\theta(z-t)} - \lambda(t) R(t, z) = 0 \quad (10)$$

$$\eta T(t)^{\eta-1} \int_{t+T(t)}^{t+A(t)} R(t, z) dz - T(t)^\eta R(t, t + T(t)) = 0, \quad (11)$$

where $\lambda(t)$ is the Lagrangean multiplier associated to the inter-temporal budget constraint. Since $R(t, t) = 1$ and $m(0, t) = 1$, we obtain from equation (10) $\lambda(t) = 1$. Using this in (9), we may rewrite contingent prices as

$$R(t, z) = m(z - t, t) e^{-\theta(z-t)}. \quad (12)$$

Equation (12) reflects that, with linear utility, contingent prices are just equal to the discount factor in utility, which includes the survival probabilities.

The first order necessary condition for the schooling time is (11). The first term is the marginal gain of increasing the time spent at school and the second is the marginal cost, i.e., the loss in wage income if the entry on the job market is delayed.

From (11) and (12) the solution for $T(t)$ should satisfy:

$$T(t) m(T(t), t) e^{-\theta T(t)} = \int_{T(t)}^{A(t)} m(a, t) e^{-\theta a} da, \quad (13)$$

where the right hand side represents the discounted flow of wages per unit of human capital.

Aggregate Human Capital

The productive aggregate stock of human capital is computed from the human capital of all generations currently at work:

$$H(t) = \int_{t-\bar{A}(t)}^{t-\bar{T}(t)} \zeta e^{n(z)z} m(t-z, z) h(z) dz, \quad (14)$$

where $t - \bar{T}(t)$ is the last generation that entered the job market at t and $t - \bar{A}(t)$ is the oldest generation still alive at t . Then, $\bar{T}(t) = T(t - \bar{T}(t))$.

The average human capital at the root of the externality (9) is obtained by dividing the aggregate human capital by the size of the population given in (5):

$$\bar{H}(t) = \frac{H(t)}{P(t)}. \quad (15)$$

The dynamics of human capital accumulation can be obtained by combining (9) with (14) and (15):

$$H(t) = \int_{t-\bar{A}(t)}^{t-\bar{T}(t)} \zeta e^{n(z)z} m(t-z, z) \frac{\mu T(z)^\eta H(z)}{\eta P(z)} dz \quad (16)$$

To evaluate $H(t)$, for $t \geq 0$, we need to know initial conditions for $H(t)$, for $t \in [-\bar{A}(0), 0]$.

The Balanced Growth Path

Let us define a balanced growth path as a situation where human capital and output grow at a constant rate in a stationary environment. By a stationary environment we mean $n(t) = n$, $\alpha(t) = \alpha$ and $\beta(t) = \beta$, for all t , which implies that $m(a, t) = m(a)$.

From (13), the stationary solution for T should satisfy the following condition:

$$T m(T) e^{-\theta T} = \int_T^A m(a) e^{-\theta a} da. \quad (17)$$

From (16), there exists a balanced growth path $H(t) = He^{\gamma t}$, with H and γ both constant, H nonzero, if and only if the following integral equation holds:

$$\frac{\mu T^\eta}{\eta \kappa} \int_T^A m(z) e^{-\gamma z} dz = 1 \quad \text{with} \quad \kappa = \int_0^A m(a) e^{-\eta a} da. \quad (18)$$

As it is standard in endogenous growth models, the constant H depends on initial conditions. Under slightly different assumptions, Boucekine, de la Croix, and Licandro (2002) show that this type of economy has a unique balanced growth path and that the economy converges to it by oscillations. In the next section, we study the empirical implications of our model, regarding the contribution of the decline in mortality to launching modern growth.

4 Empirical assessment

We first adapt our model in order to fit the main facts outlined in Section 2.

The empirical model

In order to focus on adult mortality, we disregard the huge swings affecting infant mortality in the 17th, 18th and early 19th centuries. Consistently with our statistical treatment in Section 2 where the survival laws from Geneva and Venice data are normalized to 1000 at age 10, we will consider that the birth date in our model corresponds to age 10 in the data. One decision variable is affected by this time shift, the schooling time, $T(t)$. If the birth date is 10, one can legitimately argue that the true schooling time is not $T(t)$, but $T(t) + T_0$, where T_0 is the time spent at school before 10. In our empirical assessment, we take into account this crucial aspect and replace $T(t)$ with $T(t) + T_0$ in the model. More precisely, we set $T_0 = 4$, which means that the representative individual has already cumulated four years of education at birth. We shall study the sensitivity of our results to changes in actual schooling time in the sequel. With the adaptation described above, the two fundamental equations of the model giving the optimal schooling time and the law of motion of aggregate capital become respectively:

$$(T(t) + 4) m(T(t), t) e^{-\theta T(t)} = \int_{T(t)}^{A(t)} m(a, t) e^{-\theta a} da, \quad (19)$$

$$H(t) = \int_{t-\bar{A}(t)}^{t-\bar{T}(t)} \zeta e^{n(z)z} m(t-z, z) \frac{\mu(T(z) + 4)^\eta H(z)}{\eta P(z)} dz. \quad (20)$$

The corresponding steady state equations are:

$$(T + 4) m(T) e^{-\theta T} = \int_T^A m(a) e^{-\theta a} da, \quad (21)$$

$$\frac{\mu(T + 4)^\eta}{\eta \kappa} \int_T^A m(z) e^{-\gamma z} dz = 1 \quad \text{with} \quad \kappa = \int_0^A m(a) e^{-na} da. \quad (22)$$

Estimation of the survival law

We first estimate the survival function (1) for the eight periods of Figure 1 and for the four periods of Figure 2. The parameters β and α are plotted with their confidence interval in Figure 3. From this figure we first conclude that the survival laws in Geneva and Venice are very close to each other and the parameters change at the same time in both cities. Second, considering the estimates for Geneva, we observe that there are only three significantly different laws corresponding to the periods 1625-1674, 1675-1724, and 1725-1825. This is consistent with Figure 1, where we can observe that survival laws are very similar within each of these three periods.

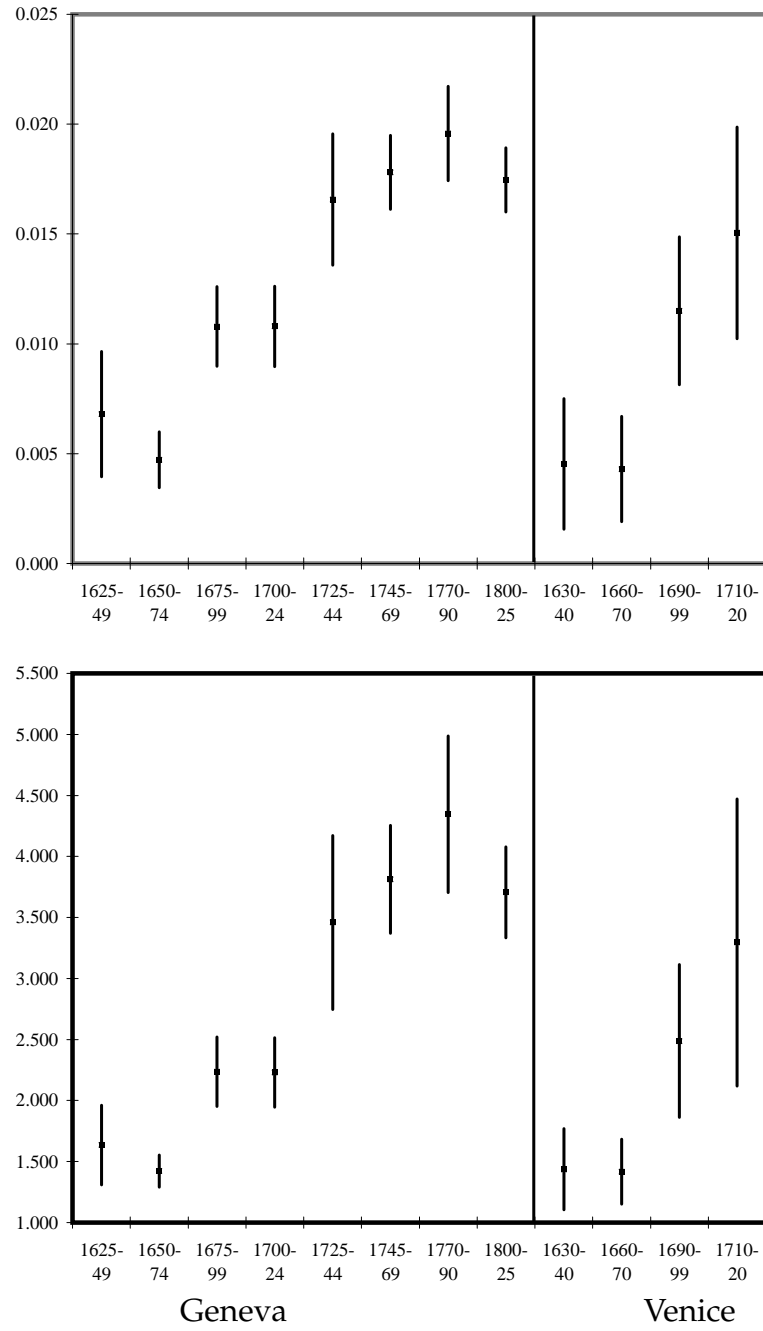
We thus assume that there are only two shifts in the parameters of the survival law. Table 3 reports these estimates and the corresponding values of the maximum age and life expectancy, which were computed from (2) and (3) respectively. To run our simulations, we have assumed that changes in the parameters of the survival law were linear and took 25 years, from 1663 to 1688 and from 1713 to 1738.

Calibration and simulation

The psychological discount parameter θ is set to a standard value of 0.04. Parameters μ and η are jointly set such that before 1663, when demographic changes started, the economy was in a balanced growth path, with GDP per capita growing at 0.1 percent (this corresponds to Maddison (1982)'s estimations for the period 1500-1700) and the age of entry in the labor market being 13 years, which correspond to $T(t) = 3$. Accordingly, $\mu = 0.2$ and $\eta = 0.4$. Note that η is the elasticity of wages to investment in education. A value of 0.4 is moderately below the 0.6 found by Heckman (1976) in contemporaneous America.

We run our simulations under the assumption that the survival probabilities were constant and the economy was in its balanced growth path from 1500 to 1663, when

Figure 3: Confidence intervals for the parameters β and α of the survival laws



the first demographic shock started. Under this assumption, we use (21) and (22) to compute the balanced growth path solution for T and γ for this period. A series for $T(t)$, from 1630 to 1820, is computed from equation (13). The effect of the mortality decline on education is displayed in Table 4. The model predicts that optimal schooling should have increased by half a year.

Finally, aggregate human capital was computed from (20), for 1663-1820, using the series for $T(t)$, $A(t)$ and $P(t)$ generated in the previous steps. Since the economy was in a balanced growth path until 1662, initial conditions for aggregate human capital are given by $H(t) = He^{\gamma t}$. The constant H is set to unity without any loss of generality. Table 5 displays the simulated average growth rates of both population and GDP. The transitory increase in the annual growth rate of population above 0.2 % is due to the improvement in longevity. The growth rate of GDP per capita moves from the initial 0.1 % to 0.14 % and then to 0.19 % over the period 1750-1820. This acceleration in growth is thus estimated to 0.09 percents per year.

Averaging over the years 1700-1820, we obtain a population growth of 0.3% and a GDP per capita growth of 0.17%. These numbers can be compared to the estimation by Maddison in table 2 of 0.4% and 0.2 % respectively. The two shifts of the survival law can thus account for half the acceleration in population growth, the rest being due to changes in fertility and/or infant mortality that we have not modelled here. Moreover, the early improvements in longevity account for 70% of the acceleration in growth over the period 1700-1820.

Note that all of these 70% are not due to the increase in schooling. Part of it simply reflects an “activity rate” effect: a drop in adult mortality increases the share of economically active persons in the society, which is favorable for growth of output per capita. To evaluate the importance of this “composition” effect compared to the one passing through human capital, we simulate the effect of changes in the mortality on growth assuming a constant $T(t)$; the results are that 28% of the acceleration in growth are accounted for by improvement in mortality when schooling is constant. The remaining 42% are thus related to a stronger accumulation of human capital.

Sensitivity experiments

It remains to assess the robustness of our predictions to changes in the parameters' values. We focus on the productivity parameters η and μ which are crucial in the determination of the optimal schooling time and the long term growth rate. More precisely, we vary η from 0.3 to 0.7 and adjust the value of μ at each η value in order to keep GDP per capita growing at 0.1 percent initially. The results are given in Table 6.

In the worse case, $\eta = 0.3$, the observed decline in adult mortality accounts for 45% of actual growth in the period 1700-1820. In such a case, actual schooling time

Table 3: Estimation of the Geneva's survival law

	1625-1674	1675-1724	1725-1825
α	1.455	2.178	3.859
β	0.0050	0.0103	0.0179
Life Exp. at 10	49.83	52.57	56.00
Max Age	84.97	85.45	85.50

Table 4: Age of entry on the labor market

	1625-1674	1675-1724	1725-1825
10 + T	13	13.2	13.57

Table 5: Simulated growth

	1500-1700	1700-1750	1750-1820
Population	0.20	0.33	0.28
GDP	0.30	0.47	0.47
GDP per capita	0.10	0.14	0.19

Table 6: Sensitivity results

η	0.3	0.4	0.5	0.6	0.7
μ	0.19	0.20	0.20	0.18	0.16
T(1600)	1.3	3	4.6	6.2	7.8
Growth 1700-1820	0.145%	0.17%	0.19%	0.21%	0.23%
% explained	45%	70%	91%	111%	128%

amounts to 5 years, to be compared to the seven years long schooling period in our reference parameterization. For high η values, when human capital formation becomes more and more elastic with respect to schooling time, the predicted growth rates exceed the actual one. In all cases, the observed changes in adult mortality appears as a fundamental determinant of the growth process in that time.

5 Conclusion

Improvements in adult mortality and in literacy have started well before the Industrial Revolution, as reported by historians. Using available survival laws for the XVIth and XVIIIth centuries, we show that life expectancy at the age of 10 has increased by 6 or 7 years over the period. The increase in life expectancy should have induced a rise in education, reflected in the observed increase of literacy. Moreover, this improvement in human capital should have pushed the growth rate up at the dawn of the Industrial Revolution, as reported by Maddison (1982) and Ladurie (1961).

In this paper, we propose an overlapping generations model where life expectancy affects positively the accumulation of human capital and growth, and use it to evaluate quantitatively the effects on growth of the observed increase in survival probabilities of adults. The parameters determining life expectancy were calibrated to replicate Geneva and Venice's survival laws over the period 1625-1825. The other parameters of the model were calibrated assuming that the economy is on a balanced growth path consistent with Maddison's observations for Europe over the period 1500-1700.

The main finding is that the observed changes in adult mortality from the late quarter of the seventeenth century to the first quarter of the eighteenth century have played a fundamental role in launching modern growth. In our reference parameterization with a schooling time amounting to 7 years, the decline in adult mortality has induced an increase in the growth rate of around 70% of the increase estimated by Maddison. Our study thus promotes the view that the early decline in adult mortality is responsible for a large part of the acceleration of growth at the dawn of the modern ages.

The question on the agenda is twofold. First, it should be important to evaluate to what extent a higher literacy rate was a necessary condition to develop and adopt new technologies, so paving the way for the industrial revolution. Second, the feedback from growth to mortality occurring in the nineteenth and twentieth centuries should be analyzed in an endogenous growth model where health expenditures allow for a reduction in mortality rates.

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